

## **Appendix J**

### **Air Pollution Control Device Cost Models**

New Polishing FF  
FF Moderate DOM  
FF Small DOM  
Advanced FF

New ESP  
ESP Moderate DOM  
ESP Small DOM

New Low Energy Wet Scrubber  
Low Energy Wet Scrubber Moderate DOM  
Low Energy Wet Scrubber Small DOM

High Energy Wet Scrubber Moderate DOM  
High Energy Wet Scrubber Small DOM

Dry Scrubber

Water Quench Cooler

Activated Carbon Injection

Activated Carbon Bed

Reheater

Combustor DOM

## Fabric Filter -- Cost Model

	A	B	C
1	<b>Fabric Filter -- Cost Model</b>		
2			
3	<b>Annual Costs</b>		
4	Total Annual Costs	A1	=C104+C97+C109
5	Annual Operating Cost	A2	=C4-C103
6	Annualized Capital Cost	A3	=C103
7	Fixed Annual O&M Costs	A4	=C97+C104-C6
8	Variable Annual O&M Costs	A5	=C109
9	Capacity (acfy)	A6	=C16*60*C18
10	Variable Annual Costs (\$ / 10^6 acfy)	A7	=C8*10^6/C9
11			
12	<b>Capital Investment</b>		
13	Total Capital Investment (TCI) (DC+TIC)	B1	=C77+C86
14			
15	<b>Model Plant Input Parameters</b>		
16	Flue Gas Flow Rate (acfm)	C1	66870.6
17	Flue Gas Flow Rate (dscfm)	C2	32120.3
18	Operational Time (hr/yr)	C5	8000
19			
20	<b>Control Option Design Input Parameters</b>		
21	Increased Pressure Drop (in. H2O)	D2	5
22	FF Bag Material Cost, fiberglass w/ 10% TFE (\$/sq ft)	D8	2
23	FF Gas-to-Cloth Ratio (aft/min)	D9	6
24	FF Bag Replacement Labor Rate (\$/sq ft)	D10	1.67
25			
26	<b>Economic Factors</b>		
27	Projected FF Equipment Life (years)	E1	20
28	Projected FF Bag Life (years)	E2	2
29	Interest Rate (%)	E3	0.07
30	Equipment Capital Recovery Factor (CRF)	E4	0.094
31	Retrofit Factor (RF)	E5	1.4
32	Operator Labor (\$/hr)	E6	17.26
33	Maintenance Labor (\$/hr)	E7	18
34	Electricity Cost (\$/kwh)	E8	0.067
35	Water Cost (\$/1000 gal)	E9	0.2
36	Wastewater Disposal (\$/1000 lb)	E10	1.2
37	Hazardous Waste Disposal Cost (\$/ton)	E11	900
38	FF Bag Capital Recovery Factor (CRFbag)	E12	=C29*(1+C29)^C28/((1+C29)^C28-1)
39			
40	<b>Emissions Levels</b>		
41	Existing PM Stack Emissions (gr/dscf)	F1	0.04
42	Desired PM Stack Emissions (gr/dscf)	F2	0.015
43			
44	<b>Model Plant Calculated Parameters</b>		
45	FF Required Cloth Area (sq ft)	G7	=C16/C23
46			
47	<b>Estimating Equipment Cost based on FF Size</b>		
48	Pulse Jet Fabric Filter		
49	Cost Without Bags	H1	=13540+8.885*C45
50	Insulation Add-on	H2	=1041+2.23*C45
51	Bare Baghouse Cost (Baghouse + Insulation)	H7	=SUM(C49:C50)
52	Bag Cost (4.5 in. diam, 8 ft.L)	H8	=C45*C22
53	Number of bags	H9	=TRUNC(C45/9.42)+1
54	Cost for Cages, and Venturi Pulsed-air flow control	H3	=C53*(3.4217*EXP(9.42*0.0593))
55	Cost for Fan, Motor, Starter, and Other Stuff	H4	=(0.0000008*SUMSQ(C16)+0.2379*(C16) + 1983.3 )/(((964.2/505.4)*10)/16)+5000
56			
57	<b>Direct Costs</b>		
58	Purchased Equipment Costs		
59	Fabric Filter (baghouse, bags, cages, fan)	I5	=C51+C52+C54+C55
60	Total Equipment	I23	=C59
61	Instrumentation (0.1*equipment)	I24	=0.1*C60
62	Sales Taxes (0.03*equipment)	I25	=0.03*C60
63	Freight (=0.05*equipment)	I26	=0.05*C60
64	Purchased Equipment with Tax and Freight	I27	=SUM(C60:C63)
65	Purchased Equipment with Escalation	I28	=C64*1.16885*1.045
66	Total Purchased Equipment Cost	I30	=C65
67	Direct Installation Costs		
68	Foundations and supports (0.04*PEC)	I31	=0.04*C66

Fabric Filter -- Cost Model

	A	B	C
69	Handling and erection (0.5*PEC)	I32	=0.5*C66
70	Electrical (0.08*PEC)	I33	=0.08*C66
71	Piping (0.01*PEC)	I34	=0.01*C66
72	Insulation for ductwork (0.07*PEC)	I35	=0.07*C66
73	Painting (0.02*PEC)	I36	=0.02*C66
74	Total Installation Costs	I47	=SUM(C68:C73)
75	Total Installation Costs with Retrofit Factor	I48	=C74*C31
76	Total Direct Installation Cost	I49	=C75
77	Total Direct Cost (DC) (PEC+DIC*RF)	I50	=C76+C66
78			
79	<b>Indirect Installation Costs</b>		
80	Engineering (0.1*PEC)	J1	=0.1*C66
81	Construction and Field Expense (0.2*PEC)	J2	=0.2*C66
82	Contractor Fees (0.1*PEC)	J3	=0.1*C66
83	Start-up (0.01*PEC)	J4	=0.01*C66
84	Performance Test (0.01*PEC)	J5	=0.01*C66
85	Contingencies (0.06*PEC)	J7	=0.06*C66
86	Total Indirect Costs (TIC)	J8	=SUM(C80:C85)
87			
88	<b>Fixed Annual Costs</b>		
89	Direct Annual Costs		
90	Operating Labor		
91	Operator	K1	=1*C18/24*C32
92	Supervisor	K2	=0.15*C91
93	Maintenance		
94	Labor	K3	=1*3*C18/24*C33
95	Material (0.01*PEC)	K4	=0.02*C66
96	Replacement Parts, bags	K8	=(C24*C45+C53)*C38
97	Total Direct Annual Cost (TDAC)	K15	=SUM(C91:C96)
98	Indirect Annual Costs		
99	Overhead (0.6*TDAC)	L1	=0.6*(C91+C92+C94+C95)
100	Administrative Charges (0.02*TCI)	L2	=0.02*C13
101	Property Taxes (0.01*TCI)	L3	=0.01*C13
102	Insurance (0.01*TCI)	L4	=0.01*C13
103	Capital Recovery of Baghouse, Excluding Bags (CR)	L5	=C30*(C13-C96/C38)
104	Total Indirect Costs (TIAC)	L6	=SUM(C99:C103)
105	Compressed Air for Pulse		13000
106	<b>Variable Annual Costs</b>		
107	Electricity	M1	=0.000181*C16*C21*C18*C34
108	Solid Waste Disposal	M2	=(C41-C42)/7000*C17*60*C18/2000*C37
109	Total Variable Annual Costs, TVAC	M10	=SUM(C107:C108)
110			
111	Energy		
112	Electricity	kW/yr	=C107/C34/C18
113	Natural Gas	trillion Btu/yr	
114	Water	1000 gal/yr	
115	Solid Waste	tons/yr	=C108/C37
116	Liquid Waste	gal/yr	

Fabric Filter Moderate DOM -- Cost Model

	A	B	C
1	<b>Fabric Filter Moderate DOM -- Cost Model</b>		
2			
3	<b>Annual Costs</b>		
4	Total Annual Costs		=SUM(C5:C6)
5	Total Annual O&M Costs		=SUM(C7:C8)
6	Annualized Capital Cost		=C31
7	Fixed Annual O&M Costs		=C23
8	Variable Annual O&M Costs		=C25
9	Capacity (acfyr)		=C16*60*C18
10	Variable Annual Costs (\$ / 10^6 acfyr)		=C8*10^6/C9
11			
12	<b>Capital Costs</b>		
13	Install Improved Bags		=(C16/C19)*10.16*1.045
14			
15	<b>Model Plant Input Parameters</b>		
16	Flue Gas Flow Rate (acfm)		26187.6
17	Flue Gas Flow Rate (dscfm)		15837.3
18	Operational Time (hr/yr)		8000
19	Gas to Cloth Ratio (aft/min)		6
20			
21	<b>Annual O&amp;M Costs</b>		
22	<b>Fixed</b>		
23	Bag Replacement		=0.02*(C16/C19)*10.16*1.045
24	<b>Variable</b>		
25	Waste Disposal Costs		=(0.013/7000)*(60/2000)*200*8000*C17
26	Electricity		=0.000181*0.067*0.5*8000*C16
27	<b>Economic Factors</b>		
28	Projected Equipment Life (years)		3
29	Interest Rate		0.07
30	Equipment Capital Recovery Factor (CRF)		=C29*(1+C29)^C28/((1+C29)^C28-1)
31	Capital Recovery		=C13*C30
32			
33	<b>Energy</b>		
34	Electricity	kW/yr	=C26/0.067
35	Natural Gas	trillion Btu/yr	
36	Water	1000 gal/yr	
37	Solid Waste	tons/yr	=C25/200
38	Liquid Waste	gal/yr	

# Fabric Filter Small DOM -- Cost Model

	A	B	C
1	<b>Fabric Filter Small DOM -- Cost Model</b>		
2			
3	<b>Annual Costs</b>		
4	Total Annual Costs		=SUM(C5:C6)
5	Total Annual O&M Costs		=SUM(C7:C8)
6	Annualized Capital Cost		=C33
7	Fixed Annual O&M Costs		=SUM(C23:C24)
8	Variable Annual O&M Costs		=SUM(C26:C27)
9	Capacity (acfy)		=C16*60*C18
10	Variable Annual Costs (\$ / 10 <sup>6</sup> acfy)		=C8*10 <sup>6</sup> /C9
11			
12	<b>Capital Investment</b>		
13	Opacity Meter		=16000*1.5
14			
15	<b>Model Plant Input Parameters</b>		
16	Flue Gas Flow Rate (acfm)		43333.2
17	Flue Gas Flow Rate (dscfm)		25428
18	Operational Time (hr/yr)		8000
19	Gas to Cloth Ratio (aft/min)		6
20			
21	<b>Annual O&amp;M Costs</b>		
22	<b>Fixed</b>		
23	Operational Labor		=3000*(C16/24927) <sup>0.3</sup>
24	Bag Replacement		=0.05*(C16/C19)*10.16*1.045
25	<b>Variable</b>		
26	Electricity		=0.000181*0.067*0.5*8000*C16
27	Waste Disposal		=(0.005/7000)*(60/2000)*200*8000*C17
28			
29	<b>Economic Factors</b>		
30	Equipment Life (years)		10
31	Interest Rate		0.07
32	Equipment Capital Recovery Factor (CRF)		=C31*(1+C31) <sup>C30</sup> /((1+C31) <sup>C30</sup> -1)
33	Capital Recovery		=C13*C32
34			
35	<b>Energy</b>		
36	Electricity	kW/yr	=C26/0.067/C18
37	Natural Gas	trillion Btu/yr	
38	Water	1000 gal/yr	
39	Solid Waste	tons/yr	=C27/200
40	Liquid Waste	gal/yr	

Advanced Fabric Filter -- Cost Model

	A	B	C
1	<b>Advanced Fabric Filter -- Cost Model</b>		
2			
3	<b>Annual Costs</b>		
4	Total Annual Costs	A1	=C104+C97+C109
5	Annual Operating Cost	A2	=C4-C103
6	Annualized Capital Cost	A3	=C103
7	Fixed Annual O&M Costs	A4	=C97+C104-C6
8	Variable Annual O&M Costs	A5	=C109
9	Capacity (acfy)	A6	=C16*60*C18
10	Variable Annual Costs (\$ / 10^6 acfy)	A7	=C8*10^6/C9
11			
12	<b>Capital Investment</b>		
13	Total Capital Investment (TCI) (DC+TIC)	B1	=C77+C86
14			
15	<b>Model Plant Input Parameters</b>		
16	Flue Gas Flow Rate (acfm)	C1	32671.5
17	Flue Gas Flow Rate (dscfm)	C2	20473.3
18	Operational Time (hr/yr)	C5	8000
19			
20	<b>Control Option Design Input Parameters</b>		
21	Increased Pressure Drop (in. H2O)	D2	5
22	FF Bag Material Cost, fiberglass w/ 10% TFE (\$/sq ft)	D8	=2*4
23	FF Gas-to-Cloth Ratio (aft/min)	D9	2.5
24	FF Bag Replacement Labor Rate (\$/sq ft)	D10	1.67
25			
26	<b>Economic Factors</b>		
27	Projected FF Equipment Life (years)	E1	20
28	Projected FF Bag Life (years)	E2	2
29	Interest Rate (%)	E3	0.07
30	Equipment Capital Recovery Factor (CRF)	E4	0.0943929257432557
31	Retrofit Factor (RF)	E5	1.4
32	Operator Labor (\$/hr)	E6	17.26
33	Maintenance Labor (\$/hr)	E7	18
34	Electricity Cost (\$/kwh)	E8	0.067
35	Water Cost (\$/1000 gal)	E9	0.2
36	Wastewater Disposal (\$/1000 lb)	E10	1.2
37	Hazardous Waste Disposal Cost (\$/ton)	E11	900
38	FF Bag Capital Recovery Factor (CRFbag)	E12	=C29*(1+C29)^C28/((1+C29)^C28-1)
39			
40	<b>Emissions Levels</b>		
41	Existing PM Stack Emissions (gr/dscf)	F1	0.08
42	Desired PM Stack Emissions (gr/dscf)	F2	0.015
43			
44	<b>Model Plant Calculated Parameters</b>		
45	FF Required Cloth Area (sq ft)	G7	=C16/C23
46			
47	<b>Estimating Equipment Cost based on FF Size</b>		
48	Pulse Jet Fabric Filter		
49	Cost Without Bags	H1	=13540+8.885*C45
50	Insulation Add-on	H2	=1041+2.23*C45
51	Bare Baghouse Cost (Baghouse + Insulation)	H7	=SUM(C49:C50)
52	Bag Cost (4.5 in. diam, 8 ft.L)	H8	=C45*C22
53	Number of bags	H9	=TRUNC(C45/9.42)+1
54	Cost for Cages, and Venturi Pulsed-air flow control	H3	=C53*(3.4217*EXP(9.42*0.0593))
55	Cost for Fan, Motor, Starter, and Other Stuff	H4	=(0.0000008*SUMSQ(C16)+0.2379*(C16) + 1983.3 )*((964.2/505.4)*10)/16)+5000
56			
57	<b>Direct Costs</b>		
58	Purchased Equipment Costs		
59	Fabric Filter (baghouse, bags, cages, fan)	I5	=C51+C52+C54+C55
60	Total Equipment	I23	=C59
61	Instrumentation (0.1*equipment)	I24	=0.1*C60
62	Sales Taxes (0.03*equipment)	I25	=0.03*C60
63	Freight (=0.05*equipment)	I26	=0.05*C60
64	Purchased Equipment with Tax and Freight	I27	=SUM(C60:C63)
65	Purchased Equipment with Escalation	I28	=C64*1.16885*1.045
66	Total Purchased Equipment Cost	I30	=C65
67	Direct Installation Costs		
68	Foundations and supports (0.04*PEC)	I31	=0.04*C66

Advanced Fabric Filter -- Cost Model

	A	B	C
69	Handling and erection (0.5*PEC)	I32	=0.5*C66
70	Electrical (0.08*PEC)	I33	=0.08*C66
71	Piping (0.01*PEC)	I34	=0.01*C66
72	Insulation for ductwork (0.07*PEC)	I35	=0.07*C66
73	Painting (0.02*PEC)	I36	=0.02*C66
74	Total Installation Costs	I47	=SUM(C68:C73)
75	Total Installation Costs with Retrofit Factor	I48	=C74*C31
76	Total Direct Installation Cost	I49	=C75
77	Total Direct Cost (DC) (PEC+DIC*RF)	I50	=C76+C66
78			
79	<b>Indirect Installation Costs</b>		
80	Engineering (0.1*PEC)	J1	=0.1*C66
81	Construction and Field Expense (0.2*PEC)	J2	=0.2*C66
82	Contractor Fees (0.1*PEC)	J3	=0.1*C66
83	Start-up (0.01*PEC)	J4	=0.01*C66
84	Performance Test (0.01*PEC)	J5	=0.01*C66
85	Contingencies (0.06*PEC)	J7	=0.06*C66
86	Total Indirect Costs (TIC)	J8	=SUM(C80:C85)
87			
88	<b>Fixed Annual Costs</b>		
89	Direct Annual Costs		
90	Operating Labor		
91	Operator	K1	=6*C18/24*C32
92	Supervisor	K2	=0.15*C91
93	Maintenance		
94	Labor	K3	=0.5*3*C18/24*C33
95	Material (0.01*PEC)	K4	=0.02*C66
96	Replacement Parts, bags	K8	=(C24*C45+C53)*C38
97	Total Direct Annual Cost (TDAC)	K15	=SUM(C91:C96)
98	Indirect Annual Costs		
99	Overhead (0.6*TDAC)	L1	=0.6*(C91+C92+C94+C95)
100	Administrative Charges (0.02*TCI)	L2	=0.02*C13
101	Property Taxes (0.01*TCI)	L3	=0.01*C13
102	Insurance (0.01*TCI)	L4	=0.01*C13
103	Capital Recovery of Baghouse, Excluding Bags (CR)	L5	=C30*(C13-C96/C38)
104	Total Indirect Costs (TIAC)	L6	=SUM(C99:C103)
105	Compressed Air for Pulse		13000
106	<b>Variable Annual Costs</b>		
107	Electricity	M1	=0.000181*C16*C21*C18*C34
108	Solid Waste Disposal	M2	=(C41-C42)/7000*C17*60*C18/2000*C37
109	Total Variable Annual Costs, TVAC	M10	=SUM(C107:C108)
110			
111	Energy		
112	Electricity	kW/yr	=C107/C34/C18
113	Natural Gas	trillion Btu/yr	
114	Water	1000 gal/yr	
115	Solid Waste	tons/yr	=C108/C37
116	Liquid Waste	gal/yr	

Electrostatic Precipitator -- Cost Model

	A	B	C
1	<b>Electrostatic Precipitator -- Cost Model</b>		
2			
3	Annual Costs		
4	Total Annual Costs	A1	=C89+C81
5	Annual Operating Cost	A2	=C4-C88
6	Annualized Capital Cost	A3	=C88
7			
8	Capital Investment		
9	Total Capital Investment	B1	=C59+C69
10			
11	Model Plant Input Parameters		
12	Flue Gas Flow Rate (acfm)	C1	45443.5
13	Flue gas flow rate (dscfm)	C2	22583
14	Operational time (hr/yr)	C5	8000
15			
16	Control Option Design Input Parameters		
17	Specific Collection Area	D1	250
18	Increased Pressure Drop (in H2O)	D2	3
19			
20	Economic Factors		
21	Projected Equipment Life (years)	E1	20
22	Interest Rate (%)	E3	0.1
23	Equipment Capital Recovery Factor (CRFe)	E4	=C22*(1+C22)^C21/((1+C22)^C21-1)
24	Retrofit Factor (RF)	E5	1.25
25	Operator Labor (\$/hr)	E6	14
26	Maintenance Labor (\$/hr)	E7	18
27	Electricity Cost (\$/kwh)	E8	0.048
28	Water Cost (\$/1000 gal)	E9	0.2
29	Wastewater Disposal (\$/1000 lb)	E10	0.8
30	Hazardous Waste Disposal Cost (\$/ton)	E11	150
31			
32	Emissions Levels		
33	Existing PM stack emissions, (gr/dscf)	F1	0.08
34	Desired stack emissions, (gr/dscf)	F2	0.015
35			
36	Model Plant Calculated Parameters		
37	ESP Total Collection Area (sq ft)	G1	=(C12/1000)*C17
38			
39	Direct Cost		
40	Purchased Equipment Cost		
41	ESP + Auxiliary Equipment	I1	=IF(C37>=50000,83.91*C37^0.8431,891.1*C37^0.6276)
42	Total Equipment	I23	=C41
43	Instrumentation	I24	=0.1*C42
44	Sales Tax	I25	=0.03*C42
45	Freight	I26	=0.05*C42
46	Purchased Equipment with Tax and Freight	I27	=SUM(C42:C45)
47	Purchased Equipment with Escalation	I28	=C46*1.1611
48	Total Purchased Equipment Cost	I30	=C47
49	Direct Installation Costs		
50	Foundation and Supports (0.04*PEC)	I31	=0.04*C48
51	Handling and Erection (0.5*PEC)	I32	=C48*0.5
52	Electrical (.08*PEC)	I33	=0.08*C48
53	Piping (.01*PEC)	I34	=0.01*C48
54	Insulation for Ductwork (.02*PEC)	I35	=0.02*C48
55	Painting (.02*PEC)	I36	=0.02*C48
56	Total Installation Cost	I47	=SUM(C50:C55)
57	Total Installation Cost with Retrofit Factor	I48	=C56*C24
58	Total Direct Installation Cost	I49	=C57
59	Total Direct Cost	I50	=C58+C48
60			
61	Indirect Cost		
62	Engineering (0.2*PEC)	J1	=0.2*C48
63	Construction and Field Expensive (0.2*PEC)	J2	=0.2*C48



## Electrostatic Precipitator -- Cost Model

	A	B	C
64	Contractor Fees (.01*PEC)	J3	=0.1*C48
65	Start-up (.01*PEC)	J4	=0.01*C48
66	Performance Test (.01*PEC)	J5	=0.01*C48
67	Model Study (.02*PEC)	J6	=0.02*C48
68	Contingencies (.03*PEC)	J7	=0.03*C48
69	Total Indirect Cost	J8	=SUM(C62:C68)
70			
71	Direct Annual Cost		
72	Operating Labor		
73	Operator Labor	K1	=2*3*C14/24*C25
74	Supervisor Labor	K2	=0.15*C73
75	Maintenance		
76	Maintenance Labor	K3	=0.5*3*C14/24*C26
77	Maintenance Material (.01*PEC)	K4	=0.01*C48
78	Utilities		
79	Electricity	K5	=C37*C14*C27*0.00194+0.000181*C12*C18*C14*C27
80	Solid Waste Disposal	K13	=(C33-C34)/7000/2000*C13*60*C14*C30
81	Total Direct Annual Cost	K15	=SUM(C73:C80)
82			
83	Indirect Annual Cost		
84	Overhead	L1	=0.6*(C73+C74+C76+C77)
85	Administrative Charges	L2	=0.02*C9
86	Property Taxes	L3	=0.01*C9
87	Insurance	L4	=0.01*C9
88	Capital Recovery	L5	=C23*C9
89	Total Indirect Annual Cost	L6	=SUM(C84:C88)
90			
91	CKRC May 3rd report		
92	esp + fan		=8.22*C12
93	total captial costs		=2.07*C92

Electrostatic Precipitator Moderate DOM -- Cost Model

	A	B	C
1	<b>Electrostatic Precipitator Moderate DOM -- Cost Model</b>		
2			
3	<b>Annual Costs</b>		
4	Total Annual Costs	A1	=C91+C84+C97
5	Annual Operating Cost	A2	=C4-C90
6	Annualized Capital Cost	A3	=C90
7	Fixed Annual O&M Costs	A4	=C84+C91-C6
8	Variable Annual O&M Costs	A5	=C97
9	Capacity (acfy)	A6	=C16*60*C19
10	Variable Annual Costs (\$ / 10^6 acfy)	A7	=C8*10^6/C9
11			
12	<b>Capital Investment</b>		
13	Total Capital Investment	B1	=C66+C74
14			
15	<b>Model Plant Input Parameters</b>		
16	Flue Gas Flow Rate (acfm)	C1	148333.9
17	Flue Gas Flow Rate (dscfm)	C2	91507
18	Flue Gas Moisture (%)	C4	6.6
19	Operational Time (hr/yr)	C5	8000
20	System Type		Liquid boiler
21			
22	<b>Control Option Design Input Parameters</b>		
23	Increased Pressure Drop (in H2O)	D2	2
24	Water Quench Temperature Drop (°F)	D3	200
25	Flue Gas Density @STP (lb/ft^3)	D33	0.074
26	Specific Heat of Flue Gas (Btu/lb°F)	D34	0.24
27	Pump Head Loss (ft)	D37	400
28	New Duct Length (ft)	D38	20
29			
30	<b>Economic Factors</b>		
31	Projected Equipment Life (years)	E1	15
32	Interest Rate (%)	E3	0.07
33	Equipment Capital Recovery Factor (CRF)	E4	=C32*(1+C32)^C31/((1+C32)^C31-1)
34	Retrofit Factor (RF)	E5	1.2
35	Operator Labor (\$/hr)	E6	14
36	Maintenance Labor (\$/hr)	E7	18
37	Electricity Cost (\$/kwh)	E8	0.048
38	Water Cost (\$/1000 gal)	E9	0.2
39	Wastewater Disposal (\$/1000 lb)	E10	0.8
40	Hazardous Waste Disposal Cost (\$/ton)	E11	200
41			
42	<b>Emissions Levels</b>		
43	Existing PM Stack Emissions (gr/dscf)	F1	0.03
44	Desired Stack Gas Emissions (gr/dscf)	F2	0.015
45			
46	<b>Model Plant Calculated Parameters</b>		
47	WQ Water Requirement (gpm)	G2	=C17/((1-(C18/100))^C25*C26*C24/900/8.33
48			
49	<b>Direct Costs</b>		
50	Purchased Equipment Costs (PEC)		
51	Spray Cooling System	I3	=80000*(C17/100000)^0.7
52	Ductwork	I4	=0.981*C28*(1.25*C16)^0.5
53	APCD insulation		=2000+0.8*(C16/2)
54	Duct insulation		=IF(C20="Lightweight aggregate kiln",50000,0)
55	Total Equipment	I23	=SUM(C51:C54)
56	Sales Tax	I25	=C55*0.03
57	Freight	I26	=C55*0.05
58	Purchased Equipment with Tax and Freight	I27	=SUM(C55:C57)
59	Purchased Equipment with Escalation	I28	=C58*1.1391*1.198
60	Purchased Equipment with Retrofit Factor	I29	=C59*C34
61	Total Purchased Equipment Cost	I30	=C60
62	Direct Installation Costs		
63	Installation Cost	I37	=0.56*C61

## Electrostatic Precipitator Moderate DOM -- Cost Model

	A	B	C
64	Total Installation Cost	I47	=C63
65	Total Direct Installation Cost	I49	=C64
66	Total Direct Costs	I50	=C61+C65
67			
68	<b>Indirect Costs</b>		
69	Engineering (=0.05*PEC)	J1	=0.05*C60
70	Construction and Field Expense (0.16*PEC)	J2	=0.16*C60
71	Contractor Fees (0.1*PEC)	J3	=0.1*C60
72	Start-up (0.01*PEC)	J4	=0.01*C60
73	Contingencies (0.06*PEC)	J7	=0.06*C60
74	Total Indirect Costs (TIC)	J8	=SUM(C69:C73)
75			
76	<b>Fixed Annual Costs</b>		
77	Direct Annual Costs		
78	Operating Labor		
79	Operator Labor	K1	=0.5*3*C19/24*C35
80	Supervisor Labor	K2	=0.15*C79
81	Maintenance		
82	Maintenance Labor	K3	=0.5*3*C19/24*C36
83	Maintenance Material	K4	=0.01*C13
84	Total Direct Annual Costs, TDAC	K15	=SUM(C79:C83)
85	Indirect Annual Costs		
86	Overhead (OH)	L1	=0.6*(C79+C80+C82+C83)
87	Administrative (0.02*TCI)	L2	=0.02*C13
88	Property Taxes (0.01*TCI)	L3	=0.01*C13
89	Insurance (0.01*TCI)	L4	=0.01*C13
90	Capital Recovery (CR)	L5	=C13*C33
91	Total Indirect Annual Cost, TIAC	L6	=SUM(C86:C90)
92			
93	<b>Variable Annual Costs</b>		
94	Electricity Cost	M1	=0.000181*C16*C23*C19*C37+(C27*C47*1/3960/1.34/0.9*C19*C37)
95	Water Cost	M3	=C47*60*C19/1000*C38
96	Solid Waste Disposal	M2	=(C43-C44)/7000*C17*60*C19*C40/2000
97	Total Variable Annual Costs, TVAC	M10	=SUM(C94:C96)
98			
99	Energy		
100	Electricity	kW/yr	=C94/C37/C19
101	Natural Gas	trillion Btu/yr	
102	Water	1000 gal/yr	=C95/C38
103	Solid Waste	tons/yr	=C96/C40
104	Liquid Waste	gal/yr	

# Electrostatic Precipitator Small DOM -- Cost Model

	A	B	C
1	<b>Electrostatic Precipiator Small DOM -- Cost Model</b>		
2			
3	<b>Annual Costs</b>		
4	Total Annual Costs		=SUM(C5:C6)
5	Total Annual O&M Costs		=SUM(C7:C8)
6	Annualized Capital Cost		=C32
7	Fixed Annual O&M Costs		=SUM(C24:C24)
8	Variable Annual O&M Costs		=SUM(C26:C26)
9	Capacity (acfyr)		=C18*60*C20
10	Variable Annual Costs (\$ / 10^6 acfyr)		=C8*10^6/C9
11			
12	<b>Capital Investment</b>		
13	<b>Total</b>		=SUM(C14:C15)
14	Opacity Meter		=16000*1.55165
15	ESP Replacement Parts		=70000*(C18/100000)^0.7
16			
17	<b>Model Plant Input Parameters</b>		
18	Flue Gas Flow Rate (acfm)		148333.9
19	Flue Gas Flow Rate (dscfm)		91507
20	Operational Time (hr/yr)		8000
21			
22	<b>Annual O&amp;M Costs</b>		
23	<b>Fixed</b>		
24	Enhanced O&M Labor/Parts		=5000*(C18/24927)^0.3
25	<b>Variable</b>		
26	Waste Disposal Costs		=(0.005/7000)*(60/2000)*200*8000*C19
27			
28	<b>Economic Factors</b>		
29	Projected Equipment Life (years)		10
30	Interest Rate		0.07
31	Equipment Capital Recovery Factor (CRF)		=C30*(1+C30)^C29/((1+C30)^C29-1)
32	Capital Recovery		=(C14+C15)*C31
33			
34	Energy		
35	Electricity	kW/yr	
36	Natural Gas	trillion Btu/yr	
37	Water	1000 gal/yr	
38	Solid Waste	tons/yr	=C26/200
39	Liquid Waste	gal/yr	

# Low Energy Wet Scrubber -- Cost Model

	A	B	C
1	<b>Low Energy Wet Scrubber -- Cost Model</b>		
2			
3	<b>Annual Costs</b>		
4	Total Annual Costs	A1	=C99+C92+C106
5	Annual Operating Cost	A2	=C4-C98
6	Annualized Capital Cost	A3	=C98
7	Fixed Annual O&M Costs	A4	=C99+C92-C6
8	Variable Annual O&M Costs	A5	=C106
9	Capacity (acfy)	A6	=C16*60*C19
10	Variable Annual Costs (\$ / 10^6 acfy)	A7	=C8*10^6/C9
11			
12	<b>Capital Investment</b>		
13	Total Capital Investment	B1	=C82+C73
14			
15	<b>Model Plant Input Parameters</b>		
16	Flue Gas Flow Rate (acfm)	C1	148333.9
17	Flue Gas Flow Rate (dscfm)	C2	91507
18	HCl Inlet (ppmv)	C3	67.9
19	Operational Time (hr/yr)	C5	8000
20			
21	<b>Control Option Design Input Parameters</b>		
22	Liquid/Gas Ratio (gpm/1000 acfm)	D18	20
23	Water Make-up Rate (% of recirc rate)	D19	0.2
24	Sorbent HCl stoichiometry	D20	1.1
25	Scrubber Packing Depth (ft)	D23	10
26	NaOH Cost (\$/ton)	D24	500
27	Scrubber Pressure Drop (in H2O/ft packing)	D25	1
28	Scrubber Packing Cost (\$/ft3)	D26	70
29	Pump Head Loss (ft)	D37	100
30			
31	<b>Economic Factors</b>		
32	Projected Equipment Life (years)	E1	10
33	Interest Rate (%)	E3	0.07
34	Equipment Capital Recovery Factor (CRF)	E4	=C33*(1+C33)^C32/((1+C33)^C32-1)
35	Retrofit Factor (RF)	E5	1.4
36	Operator Labor (\$/hr)	E6	14
37	Maintenance Labor (\$/hr)	E7	18
38	Electricity Cost (\$/kwh)	E8	0.048
39	Water Cost (\$/1000 gal)	E9	0.2
40	Wastewater Disposal (\$/1000 lb)	E10	1.2
41	Hazardous Waste Disposal Cost (\$/ton)	E11	900
42			
43	<b>Model Plant Calculated Parameters</b>		
44	Scrubber Recirculation Rate (gpm)	G13	=C16/1000*C22
45	Scrubber Water Makeup Rate (gpm)	G14	=C44*C23
46	Sorbent Use (lb/hr)	G15	=C17*C18/1000000*C24*60/386.7*40
47	Scrubber Blowdown Rate (lb/hr)	G16	=40*C46
48	Scrubber Diameter (ft)	G17	=0.053*C16^0.5
49	Scrubber Length (ft)	G18	=(3.9*C16^0.14)+(C25-4)
50	Scrubber Surface Area (ft2)	G19	=3.14*C48*(C49+C48/2)
51	Scrubber Packing Volume (ft^3)	G20	=3.14/4*C48^2*C25
52			
53	<b>Direct Costs</b>		
54	Purchased Equipment Costs		
55	Scrubber Tower	I16	=115*C50
56	Scrubber Packing	I17	=C51*C28
57	Scrubber Auxilliary Equipment Cost	I18	=(C55+C56)*1
58	Total Equipment	I23	=SUM(C55:C57)
59	Sales Tax	I25	=0.03*C58
60	Freight	I26	=0.05*C58
61	Purchased Equipment with Tax and Freight	I27	=SUM(C58:C60)
62	Total Purchase Equipment Cost (PEC)	I30	=C61
63	Direct Installation Costs		

Low Energy Wet Scrubber -- Cost Model

	A	B	C
64	Foundation and Supports (0.06*PEC)	I31	=0.06*C62
65	Erection and Supports (0.4*PEC)	I32	=0.4*C62
66	Electrical (0.01*PEC)	I33	=0.01*C62
67	Piping (0.05*PEC)	I34	=0.05*C62
68	Insulation (0.03*PEC)	I35	=0.03*C62
69	Painting (0.01*PEC)	I36	=0.01*C62
70	Total Installation Costs	I47	=SUM(C64:C69)
71	Installation Costs with Retrofit Factor	I48	=C70*C35
72	Total Direct Installation Costs	I49	=C71
73	Total Direct Costs (TDC)	I50	=C72+C62
74			
75	<b>Indirect Installation Costs</b>		
76	Engineering (0.1*PEC)	J1	=0.1*C62
77	Construction (0.1*PEC)	J2	=0.1*C62
78	Contractor Fee (0.1*PEC)	J3	=0.1*C62
79	Start up (0.01*PEC)	J4	=0.01*C62
80	Performance Test (0.01*PEC)	J5	=0.01*C62
81	Contingency (0.06*PEC)	J7	=0.06*C62
82	Total Indirect Cost (TIC)	J8	=SUM(C76:C81)
83			
84	<b>Fixed Annual Costs</b>		
85	Direct Annual Costs		
86	Operating Labor		
87	Operator Labor	K1	=1*C19/24*C36
88	Supervisory Labor	K2	=0.15*C87
89	Maintenance		
90	Labor	K3	=1.5*3*C19/24*C37
91	Materials	K4	=0.05*C62
92	Total Direct Annual Costs (TDAC)	K15	=SUM(C87:C91)
93	Indirect Annual Costs		
94	Overhead	L1	=0.6*(C87+C88+C90+C91)
95	Administrative (0.02*TCI)	L2	=0.02*C13
96	Insurance (0.01*TCI)	L3	=0.01*C13
97	Property Tax (0.01*TCI)	L4	=0.01*C13
98	Capital Recovery (CR)	L5	=C34*C13
99	Total Indirect Annual Costs (TDIC)	L6	=SUM(C94:C98)
100			
101	<b>Variable Annual Costs</b>		
102	Electricity	M1	=0.000181*C16*(C27*C25)*C19*C38+C29*C44*1/3960/1.34/0.9*C19*C38
103	Water	M3	=C45*60*C19*C39/1000
104	Wastewater Disposal Cost	M6	=C47*C19/1000*C40
105	NaOH Cost	M7	=C46*C19/2000*C26
106	Total Variable Annual Costs (TVAC)	M10	=SUM(C102:C105)
107			
108			
109	Energy		
110	Electricity	kW/yr	=C102/C38/C19
111	Natural Gas	trillion Btu/yr	
112	Water	1000 gal/yr	=C103/C39
113	Solid Waste	tons/yr	
114	Liquid Waste	gal/yr	=C112

Low Energy Wet Scrubber Moderate DOM -- Cost Model

	A	B	C
1	<b>Low Energy Wet Scrubber Moderate DOM -- Cost Model</b>		
2			
3	<b>Annual Costs</b>		
4	Total Annual Costs		=SUM(C5:C6)
5	Total Annual O&M Costs		=SUM(C7:C8)
6	Annualized Capital Cost		=C34
7	Fixed Annual O&M Costs		0
8	Variable Annual O&M Costs		=SUM(C25:C28)
9	Capacity (acfyr)		=C19*60*C22
10	Variable Annual Costs (\$ / 10 <sup>6</sup> acfyr)		=C8*10 <sup>6</sup> /C9
11			
12	<b>Capital Investment</b>		
13	Total Capital Investment		=SUM(C14:C16)
14	New Packing / Old Packing Removal		=(1.4*1.08+2*1.4*1.08*0.1*1.25)*180*(3.14*0.053 <sup>2</sup> *C19)
15	New Pump		=1.701*C19*0.32
16	New Fan		=1.215*0.334*((3.9*C19 <sup>0.14</sup> +3)*C19) <sup>0.821</sup>
17			
18	<b>Model Plant Input Parameters</b>		
19	Flue Gas Flow Rate (acfm)		14668.4
20	Flue Gas Flow Rate (dscfm)		7503.3
21	HCl Inlet (ppmv)		18
22	Operational Time (hr/yr)		8000
23			
24	<b>Annual Variable O&amp;M Costs</b>		
25	Water Costs		=0.35*0.384*C19
26	Electricity Costs		=0.000181*0.067*3*8000*C19
27	NaOH Costs		=0.35*C20*C21*0.0118517
28	Waste Disposal Costs		=C20*C21*0.001747711*0.35
29			
30	<b>Economic Factors</b>		
31	Projected Equipment Life (years)		5
32	Interest Rate		0.07
33	Equipment Capital Recovery Factor (CRF)		=C32*(1+C32) <sup>C31</sup> /((1+C32) <sup>C31</sup> -1)
34	Capital Recovery		=C13*C33
35			
36	Energy		
37	Electricity	kW/yr	=C26/C22/0.067
38	Natural Gas	trillion Btu/yr	
39	Water	1000 gal/yr	=C25/0.2
40	Solid Waste	tons/yr	
41	Liquid Waste	gal/yr	=C39

# Low Energy Wet Scrubber Small DOM -- Cost Model

	A	B	C
1	<b>Low Energy Wet Scrubber Small DOM -- Cost Model</b>		
2			
3	<b>Annual Costs</b>		
4	Total Annual Costs		=SUM(C5:C6)
5	Total Annual O&M Costs		=SUM(C7:C8)
6	Annualized Capital Cost		=C34
7	Fixed Annual O&M Costs		0
8	Variable Annual O&M Costs		=SUM(C25:C28)
9	Capacity (acfyr)		=C22*60*C19
10	Variable Annual Costs (\$ / 10 <sup>6</sup> acfyr)		=C8*10 <sup>6</sup> /C9
11			
12	<b>Capital Investment</b>		
13	Total Capital Investment		=SUM(C14:C16)
14	Pump		=1.701*C19 <sup>0.32</sup>
15	Fan		=1.215*0.334*((3.9*C19 <sup>0.14</sup> +4)*C19) <sup>0.821</sup>
16	Tank		=1.701*(0.24*C19+1960)
17			
18	<b>Model Plant Input Parameters</b>		
19	Flue Gas Flow Rate (acfm)		14668.4
20	Flue Gas Flow Rate (dscfm)		7503.3
21	HCl Inlet (ppmv)		18
22	Operational Time (hr/yr)		8000
23			
24	<b>Annual Variable O&amp;M Costs</b>		
25	Water		=0.5*0.384*C19
26	NaOH		=0.5*C20*C21*0.0118517
27	Electricity		=0.000181*0.067*4*8000*C19
28	Waste Disposal		=C20*C21*0.001747711*0.5
29			
30	<b>Economic Factors</b>		
31	Projected Equipment Life (years)		5
32	Interest Rate		0.07
33	Equipment Capital Recovery Factor (CRF)		=C32*(1+C32) <sup>C31</sup> /((1+C32) <sup>C31</sup> -1)
34	Capital Recovery		=C13*C33
35			
36	Energy		
37	Electricity	kW/yr	=C27/C22/0.067
38	Natural Gas	trillion Btu/yr	
39	Water	1000 gal/yr	=C25/0.2
40	Solid Waste	tons/yr	
41	Liquid Waste	gal/yr	=C39



High Energy Wet Scrubber Moderate DOM -- Cost Model

	A	B	C
1	<b>High Energy Wet Scrubber Moderate DOM -- Cost Model</b>		
2			
3	<b>Annual Costs</b>		
4	Total Annual Costs		=SUM(C5:C6)
5	Total Annual O&M Costs		=SUM(C7:C8)
6	Annualized Capital Cost		=C28
7	Fixed Annual O&M Costs		0
8	Variable Annual O&M Costs		=SUM(C21:C22)
9	Capacity (acfy)		=C16*60*C18
10	Variable Annual Costs (\$ / 10 <sup>6</sup> acfy)		=C8*10 <sup>6</sup> /C9
11			
12	<b>Capital Investment</b>		
13	Fan + New or Mod Venturi Throat		=21.8*(C16 <sup>0.82</sup> )*1.078
14			
15	<b>Model Plant Input Parameters</b>		
16	Flue Gas Flow Rate (acfm)		30225.9
17	Flue Gas Flow Rate (dscfm)		22254.6
18	Operational Time (hr/yr)		8000
19			
20	<b>Annual Variable O&amp;M Costs</b>		
21	Electricity Costs		=0.000181*0.048*22*8000*C16
22	Waste Disposal Costs		=(0.013/7000)*(60/2000)*200*8000*C17
23			
24	<b>Economic Factors</b>		
25	Projected Equipment Life (years)		10
26	Interest Rate		0.07
27	Equipment Capital Recovery Factor (CRFe)		=C26*(1+C26) <sup>C25</sup> /((1+C26) <sup>C25</sup> -1)
28	Capital recovery		=C13*C27
29			
30	Energy		
31	Electricity	kW/yr	=C21/0.048/C18
32	Natural Gas	trillion Btu/yr	
33	Water	1000 gal/yr	
34	Solid Waste	tons/yr	=C22/200
35	Liquid Waste	gal/yr	

# High Energy Wet Scrubber Small DOM -- Cost Model

	A	B	C
1	<b>High Energy Wet Scrubber Small DOM -- Cost Model</b>		
2			
3	<b>Annual Costs</b>		
4	Total Annual Costs		=SUM(C5:C6)
5	Total Annual O&M Costs		=SUM(C7:C8)
6	Annualized Capital Cost		=C28
7	Fixed Annual O&M Costs		0
8	Variable Annual O&M Costs		=SUM(C21:C22)
9	Capacity (acfyr)		=C16*60*C18
10	Variable Annual Costs (\$ / 10^6 acfyr)		=C8*10^6/C9
11			
12	<b>Capital Investment</b>		
13	Fan + New or Mod Venturi Throat		=21.8*(C16^0.82)*1.078
14			
15	<b>Model Plant Input Parameters</b>		
16	Flue Gas Flow Rate (acfm)		30225.9
17	Flue Gas Flow Rate (dscfm)		22254.6
18	Operational Time (hr/yr)		8000
19			
20	<b>Annual Variable O&amp;M Costs</b>		
21	Electricity Costs		=0.000181*0.048*7*8000*C16
22	Waste Disposal Costs		=(0.013/7000)*(60/2000)*200*8000*C17
23			
24	<b>Economic Factors</b>		
25	Projected Equipment Life (years)		10
26	Interest Rate		0.07
27	Equipment Capital Recovery Factor (CRF)		=C26*(1+C26)^C25/((1+C26)^C25-1)
28	Capital Recovery		=C13*C27
29			
30	Energy		
31	Electricity	kW/yr	=C21/C18/0.048
32	Natural Gas	trillion Btu/yr	
33	Water	1000 gal/yr	
34	Solid Waste	tons/yr	=C22/200
35	Liquid Waste	gal/yr	

Dry Scrubbing -- Cost Model

	A	B	C
1	<b>Dry Scrubbing -- Cost Model</b>		
2			
3	<b>Annual Costs</b>		
4	Total Annual Cost	A1	=C58+C51+C65
5	Annual Operating Cost	A2	=C4-C57
6	Annualized Capital Cost	A3	=C57
7	Fixed Annual O&M Costs	A4	=C58+C51-C6
8	Variable Annual O&M Costs	A5	=C65
9	Capacity (acfyr)	A6	=C16*60*C20
10	Variable Annual Costs (\$ / 10^6 acfyr)	A7	=C8*10^6/C9
11			
12	<b>Capital Investment</b>		
13	Total Capital Investment (TCI) (DC+TIC)	B1	=100000*(C17/30000)^0.7
14			
15	<b>Model Plant Input Parameters</b>		
16	Flue Gas Flow Rate (acfm)	C1	95937.4
17	Flue Gas Flow Rate (dscfm)	C2	32666.6
18	HCl Inlet (ppmv)	C3	0.43
19	SO2 (ppmv)		0
20	Operational Time (hr/yr)	C5	8000
21			
22	<b>Control Option Design Input Parameters</b>		
23	Increased Pressure Drop (in H2O)	D2	2
24	Sorbent HCl stoichiometry	D20	2.5
25	Ca(OH)2 cost (\$/ton)	D21	95
26			
27	<b>Economic Factors</b>		
28	Projected Equipment Life (years)	E1	10
29	Interest Rate (%)	E3	0.07
30	Equipment Capital Recovery Factor (CRF)	E4	=C29*(1+C29)^C28/((1+C29)^C28-1)
31	Retrofit Factor (RF)	E5	1.15
32	Operator Labor (\$/hr)	E6	14
33	Maintenance Labor (\$/hr)	E7	18
34	Electricity Cost (\$/kwh)	E8	0.048
35	Water Cost (\$/1000 gal)	E9	0.2
36	Wastewater Disposal (\$/1000 lb)	E10	0.8
37	Hazardous Waste Disposal Cost (\$/ton)	E11	200
38			
39	<b>Model Plant Calculated Parameters</b>		
40	Sorbent use, lb/hr	G15	=(C18/2/1000000*C17*60/386.7*74*C24)+(C19/1000000*C17*60/386.7*74*C24)
41			
42	<b>Total Capital Cost</b>		
43	Capital and Installation and Engineering		=C13
44			
45	<b>Fixed Annual Costs</b>		
46	Direct Annual Costs		
47	Operating Labor		
48	Operator	K1	=1/24*C32*C20
49	Supervisor	K2	=1/10*C48
50	Maintenance	K3	3000
51	Total Direct Annual Costs (TDAC)	K15	=SUM(C48:C50)
52	Indirect Annual Costs		
53	Overhead (OH)	L1	=0.6*SUM(C48:C50)
54	Administrative Charges (AC) (0.02*TCI)	L2	=0.02*C13
55	Property Tax (0.01*TCI)	L3	=0.01*C13
56	Insurance (0.01*TCI)	L4	=0.01*C13
57	Capital Recovery (CR)	L5	=C30*C13
58	Total Indirect Annual Cost (TIAC)	L6	=SUM(C53:C57)
59			
60	<b>Variable Annual Costs</b>		
61	Electricity	M1	=0.000181*C16*C20*C23*C34
62	Water Cost	M3	=(100*C17/940)*(8000*C35)/(1000*8.34)
63	Lime Cost	M5	=C40*C20/2000*C25

Dry Scrubbing -- Cost Model

	A	B	C
64	Solid Waste Disposal	M2	=0
65	Total Variable Annual Costs (TVAC)	M10	=SUM(C61:C64)
66			
67	Energy		
68	Electricity	kW/yr	=C61/C34/C20
69	Natural Gas	trillion Btu/yr	
70	Water	1000 gal/yr	=C62/C35
71	Solid Waste	tons/yr	=C63/C25
72	Liquid Waste	gal/yr	

Water Quench Cooling -- Cost Model

	A	B	C
1	<b>Water Quench Cooling -- Cost Model</b>		
2			
3	<b>Annual Costs</b>		
4	Total Annual Costs	A1	=C91+C84+C97
5	Annual Operating Cost	A2	=C4-C90
6	Annualized Capital Cost	A3	=C90
7	Fixed Annual O&M Costs	A4	=C84+C91-C6
8	Variable Annual O&M Costs	A5	=C97
9	Capacity (acfyr)	A6	=C16*60*C19
10	Variable Annual Costs (\$ / 10 <sup>6</sup> acfyr)	A7	=C8*10 <sup>6</sup> /C9
11			
12	<b>Capital Investment</b>		
13	Total Capital Investment	B1	=C66+C74
14			
15	<b>Model Plant Input Parameters</b>		
16	Flue Gas Flow Rate (acfm)	C1	26187.6
17	Flue Gas Flow Rate (dscfm)	C2	15837.3
18	Flue Gas Moisture (%)	C4	8.9
19	Operational Time (hr/yr)	C5	8000
20	System Type		Liquid boiler
21			
22	<b>Control Option Design Input Parameters</b>		
23	Increased Pressure Drop (in H2O)	D2	2
24	Water Quench Temperature Drop (°F)	D3	200
25	Flue Gas Density @STP (lb/ft <sup>3</sup> )	D33	0.074
26	Specific Heat of Flue Gas (Btu/lb°F)	D34	0.24
27	Pump Head Loss (ft)	D37	400
28	New Duct Length (ft)	D38	20
29			
30	<b>Economic Factors</b>		
31	Projected Equipment Life (years)	E1	15
32	Interest Rate (%)	E3	0.07
33	Equipment Capital Recovery Factor (CRF)	E4	=C32*(1+C32)^C31/((1+C32)^C31-1)
34	Retrofit Factor (RF)	E5	1.2
35	Operator Labor (\$/hr)	E6	14
36	Maintenance Labor (\$/hr)	E7	18
37	Electricity Cost (\$/kwh)	E8	0.048
38	Water Cost (\$/1000 gal)	E9	0.2
39	Wastewater Disposal (\$/1000 lb)	E10	0.8
40	Hazardous Waste Disposal Cost (\$/ton)	E11	200
41			
42	<b>Emissions Levels</b>		
43	Existing PM Stack Emissions (gr/dscf)	F1	0.03
44	Desired Stack Gas Emissions (gr/dscf)	F2	0.015
45			
46	<b>Model Plant Calculated Parameters</b>		
47	WQ Water Requirement (gpm)	G2	=C17/(1-(C18/100))*C25*C26*C24/900/8.33
48			
49	<b>Direct Costs</b>		
50	Purchased Equipment Costs (PEC)		
51	Spray Cooling System	I3	=80000*(C17/100000)^0.7
52	Ductwork	I4	=0.981*C28*(1.25*C16)^0.5
53	APCD insulation		=2000+0.8*(C16/2)
54	Duct insulation		=IF(C20="Lightweight aggregate kiln",50000,0)
55	Total Equipment	I23	=SUM(C51:C54)
56	Sales Tax	I25	=C55*0.03
57	Freight	I26	=C55*0.05
58	Purchased Equipment with Tax and Freight	I27	=SUM(C55:C57)
59	Purchased Equipment with Escalation	I28	=C58*1.1391*1.198
60	Purchased Equipment with Retrofit Factor	I29	=C59*C34
61	Total Purchased Equipment Cost	I30	=C60
62	Direct Installation Costs		
63	Installation Cost	I37	=0.56*C61

Water Quench Cooling -- Cost Model

	A	B	C
64	Total Installation Cost	I47	=C63
65	Total Direct Installation Cost	I49	=C64
66	Total Direct Costs	I50	=C61+C65
67			
68	<b>Indirect Costs</b>		
69	Engineering (=0.05*PEC)	J1	=0.05*C60
70	Construction and Field Expense (0.16*PEC)	J2	=0.16*C60
71	Contractor Fees (0.1*PEC)	J3	=0.1*C60
72	Start-up (0.01*PEC)	J4	=0.01*C60
73	Contingencies (0.06*PEC)	J7	=0.06*C60
74	Total Indirect Costs (TIC)	J8	=SUM(C69:C73)
75			
76	<b>Fixed Annual Costs</b>		
77	Direct Annual Costs		
78	Operating Labor		
79	Operator Labor	K1	=1*C19/24*C35
80	Supervisor Labor	K2	=0.15*C79
81	Maintenance		
82	Maintenance Labor	K3	=0.5*3*C19/24*C36
83	Maintenance Material	K4	=0.01*C13
84	Total Direct Annual Costs, TDAC	K15	=SUM(C79:C83)
85	Indirect Annual Costs		
86	Overhead (OH)	L1	=0.6*(C79+C80+C82+C83)
87	Administrative (0.02*TCI)	L2	=0.02*C13
88	Property Taxes (0.01*TCI)	L3	=0.01*C13
89	Insurance (0.01*TCI)	L4	=0.01*C13
90	Capital Recovery (CR)	L5	=C13*C33
91	Total Indirect Annual Cost, TIAC	L6	=SUM(C86:C90)
92			
93	<b>Variable Annual Costs</b>		
94	Electricity Cost	M1	=0.000181*C16*C23*C19*C37+(C27*C47*1/3960/1.34/0.9*C19*C37)
95	Water Cost	M3	=C47*60*C19/1000*C38
96	Solid Waste Disposal	M2	=(C43-C44)/7000*C17*60*C19*C40/2000
97	Total Variable Annual Costs, TVAC	M10	=SUM(C94:C96)
98			
99	Energy		
100	Electricity	kW/yr	=C94/C37/C19
101	Natural Gas	trillion Btu/yr	
102	Water	1000 gal/yr	=C95/C38
103	Solid Waste	tons/yr	=C96/C40
104	Liquid Waste	gal/yr	
105			

# Activated Carbon Injection -- Cost Model

	A	B	C
1	<b>Activated Carbon Injection -- Cost Model</b>		
2			
3	<b>Annual Costs</b>		
4	Total Annual Costs	A1	=C86+C79+C92
5	Annual Operating Cost	A2	=C4-C85
6	Annualized Capital Cost	A3	=C85
7	Fixed Annual O&M Costs	A4	=C86+C79-C6
8	Variable Annual O&M Costs	A5	=C92
9	Capacity (acfy)	A6	=C16*60*C18
10	Variable Annual Costs (\$ / 10 <sup>6</sup> acfy)	A7	=C8*10 <sup>6</sup> /C9
11			
12	<b>Capital Investment</b>		
13	Total Capital Investment	B1	=C69+C59
14			
15	<b>Model Plant Input Parameters</b>		
16	Flue Gas Flow Rate (acfm)	C1	66870.6
17	Flue Gas Flow Rate (dscfm)	C2	32120.3
18	Operational Time (hr/yr)	C5	8000
19			
20	<b>Control Option Design Input Parameters</b>		
21	Cost of Carbon (\$/lb)	D11	0.3
22	Carbon Injection Rate (mg/dscm)	D16	100
23	Injection Blower Fan Power (HP)	D17	15
24			
25	<b>Economic Factors</b>		
26	Projected Equipment Life (years)	E1	15
27	Interest Rate (%)	E3	0.07
28	Equipment Capital Recovery Factor (CRF)	E4	=C27*(1+C27) <sup>C26</sup> /((1+C27) <sup>C26</sup> -1)
29	Retrofit Factor (RF)	E5	1.15
30	Operator Labor (\$/hr)	E6	14
31	Maintenance Labor (\$/hr)	E7	18
32	Electricity Cost (\$/kwh)	E8	0.067
33	Water Cost (\$/1000 gal)	E9	0.2
34	Wastewater Disposal (\$/1000 lb)	E10	1.2
35	Hazardous Waste Disposal Cost (\$/ton)	E11	900
36			
37	<b>Model Plant Calculated Parameters</b>		
38	Carbon Feed Rate (lb/hr)	G11	=C22*C17/3.28 <sup>3</sup> /1000/454*60
39	Silo Storage Volume (cf)	G12	=C38*24/24*15
40			
41	<b>Direct Costs</b>		
42	Purchased Equipment Costs		
43	Storage Silo	I8	
44	Feed Bin	I9	
45	Gravimetric Feeders	I10	
46	Pneumatic Conveyor	I11	
47	Injection Ports	I12	
48	Total Equipment	I23	=90000*(C16/150000) <sup>0.7</sup>
49	Sales Tax	I25	=C48*0.03
50	Freight	I26	=C48*0.05
51	Purchased Equipment with Tax and Freight	I27	=SUM(C48:C50)
52	Purchased Equipment with Escalation	I28	=C51*1.1319*1.064
53	Purchased Equipment with Retrofit Factor	I29	=C52*C29
54	Total Purchased Equipment Cost	I30	=C53
55	Direct Installation Costs		
56	Installation Cost	I37	=0.3*C54
57	Total Installation Costs	I47	=C56
58	Total Direct Installation Cost	I49	=C57
59	Total Direct Costs (DC) (DIC+PEC)	I50	=C58+C54
60			
61	<b>Indirect Costs</b>		
62	Engineering (0.2*PEC)	J1	=0.2*C54
63	Construction and Field Expense (0.2*PEC)	J2	=0.2*C54

Activated Carbon Injection -- Cost Model

	A	B	C
1	<b>Activated Carbon Injection -- Cost Model</b>		
2			
64	Contractor Fees (0.1*PEC)	J3	=0.1*C54
65	Start-up (0.01*PEC)	J4	=0.01*C54
66	Performance Test (0.01*PEC)	J5	=0.01*C54
67	Model Study (0.02*PEC)	J6	=0.02*C54
68	Contingencies (0.06*PEC)	J7	=0.06*C54
69	Total Indirect Costs (TIC)	J8	=SUM(C62:C68)
70			
71	<b>Fixed Annual Costs</b>		
72	Direct Annual Costs		
73	Operating Labor		
74	Operator	K1	=1*C18/24*C30
75	Supervisor	K2	=0.15*C74
76	Maintenance		
77	Labor	K3	=0.5*3*C18/24*C31
78	Material (0.05*PEC)	K4	=0.05*C53
79	Total Direct Annual Costs (TDAC)	K15	=SUM(C74:C78)
80	Indirect Annual Costs		
81	Overhead	L1	=0.6*(C74+C75+C77+C78)
82	Administrative Charges (0.02*TCI)	L2	=0.02*C13
83	Property Tax (0.01*TCI)	L3	=0.01*C13
84	Insurance (0.01*TCI)	L4	=0.01*C13
85	Capital Recovery (CR) (CRF*TCI)	L5	=C28*C13
86	Total Indirect Annual Cost (TIAC)	L6	=SUM(C81:C85)
87			
88	<b>Variable Annual Costs</b>		
89	Electricity Cost	M1	=C23/1.34/0.9*C18*C32
90	Carbon Cost	M4	=C38*C18*C21
91	Solid Waste Disposal	M2	=C38*C18/2000*C35
92	Total Variable Annual Costs (TVAC)	M10	=SUM(C89:C91)
93			
94	Energy		
95	Electricity	kW/yr	=C89/C32/C18
96	Natural Gas	trillion Btu/yr	
97	Water	1000 gal/yr	
98	Solid Waste	tons/yr	=(C91/C35)+(C90/(C21*2000))
99	Liquid Waste	gal/yr	



Activated Carbon Bed -- Cost Model

	A	B	C
1	<b>Activated Carbon Bed -- Cost Model</b>		
2			
3	<b>Annual Costs</b>		
4	Total Annual Costs	A1	=C77+C70+C83
5	Annual Operating Cost	A2	=C4-C76
6	Annualized Capital Cost	A3	=C76
7	Fixed Annual O&M Costs	A4	=C70+C77-C6
8	Variable Annual O&M Costs	A5	=C83
9	Capacity (acfy)	A6	=C16*60*C18
10	Variable Annual Costs (\$ / 10^6 acfy)	A7	=C8*10^6/C9
11			
12	<b>Capital Investment</b>		
13	Total Capital Investment	B1	=C51+C60
14			
15	<b>Model Plant Input Parameters</b>		
16	Flue Gas Flow Rate (acfm)	C1	4139.1
17	Flue Gas Flow Rate (dscfm)	C2	1602.3
18	Operational Time (hr/yr)	C5	8000
19			
20	<b>Control Option Design Input Parameters</b>		
21	Cost of Carbon (\$/lb)	D11	0.5
22	Bed Pressure Drop (in H2O/ft of bed)	D12	1.5
23	Bed Velocity (m/s)	D13	0.6
24	Bed Depth (ft)	D14	=SQRT(C16/(C23*3.2808*60)/PI())*2*PI()/12
25	Carbon Exchanges (number/yr)	D15	1
26	Carbon Density (lb/ft^3)	D40	24
27			
28	<b>Economic Factors</b>		
29	Projected Equipment Life (years)	E1	15
30	Interest Rate (%)	E3	0.07
31	Equipment Capital Recovery Factor (CRFe)	E4	=C30*(1+C30)^C29/((1+C30)^C29-1)
32	Retrofit Factor (RF)	E5	1.25
33	Operator Labor (\$/hr)	E6	14
34	Maintenance Labor (\$/hr)	E7	18
35	Electricity Cost (\$/kwh)	E8	0.067
36	Water Cost (\$/1000 gal)	E9	0.2
37	Wastewater Disposal (\$/1000 lb)	E10	1.2
38	Hazardous Waste Disposal Cost (\$/ton)	E11	900
39			
40	<b>Model Plant Calculated Parameters</b>		
41	Carbon Bed Pressure Drop (in H2O)	G8	=C22*C24
42	Carbon Bed Volume (ft^3)	G9	=C16/C23/60/3.28*C24
43	Annual Carbon Consumption (lb)	G10	=C42*C25*C26
44			
45	<b>Direct Costs</b>		
46	Carbon Vessel	I7	=271*(C24*12*(C24*3+C24*6/PI()))^0.778
47	Instrumentation (0.1*equipment)	I24	=0.1*C46
48	Sales Taxes (0.03*equipment)	I25	=0.03*C46
49	Freight (0.05*equipment)	I26	=0.05*C46
50	Purchased Equipment with Tax and Freight	I27	=SUM(C46:C49)
51	Purchased Equipment with Escalation	I28	=C50*1.16885*1.045
52			
53	<b>Indirect Installation Costs</b>		
54	Engineering (0.1*PEC)	J1	=0.1*C51
55	Construction and Field Expense (0.2*PEC)	J2	=0.2*C51
56	Contractor Fees (0.1*PEC)	J3	=0.1*C51
57	Start-up (0.01*PEC)	J4	=0.01*C51
58	Performance Test (0.01*PEC)	J5	=0.01*C51
59	Contingencies (0.06*PEC)	J7	=0.06*C51
60	Total Indirect Costs (TIC)	J8	=SUM(C54:C59)
61			
62	<b>Fixed Annual Costs</b>		
63	Direct Annual Costs		

Activated Carbon Bed -- Cost Model

	A	B	C
1	<b>Activated Carbon Bed -- Cost Model</b>		
2			
64	Operating Labor		
65	Operator	K1	=1*C18/24*C33
66	Supervisor	K2	=0.15*C65
67	Maintenance		
68	Labor	K3	=0.5*3*C18/24*C34
69	Material (0.01 TCI)	K4	=0.01*C46
70	Total Direct Annual Costs (TDAC)	K15	=SUM(C65:C69)
71	Indirect Annual Costs		
72	Overhead	L1	=0.6*(C65+C66+C68+C69)
73	Administrative Charges (0.02 TCI)	L2	=0.02*C46
74	Property Tax (0.01 TCI)	L3	=0.01*C46
75	Insurance (0.01 TCI)	L4	=0.01*C46
76	Capital Recovery (CR)	L5	=C31*C51
77	Total Indirect Annual Cost (TIAC)	L6	=SUM(C72:C76)
78			
79	<b>Variable Annual Costs</b>		
80	Electricity cost (\$/yr)	M1	=0.000181*C16*C41*C18*C35
81	Carbon Cost (\$/yr)	M4	=C43*C21
82	Solid Waste Disposal	M2	=C43/2000*C38
83	Total Variable Annual Costs (TVAC)	M10	=SUM(C80:C82)
84			
85	Energy		
86	Electricity	kW/yr	=C80/C35/C18
87	Natural Gas	trillion Btu/yr	
88	Water	1000 gal/yr	
89	Solid Waste	tons/yr	=(C82/C38)+(C81/(C21*2000))
90	Liquid Waste	gal/yr	

## Reheater -- Cost Model

	A	B	C
1	<b>Reheater -- Cost Model</b>		
2			
3	<b>Annual Costs</b>		
4	Total Annual Costs	A1	=C92+C85+C97
5	Annual Operating Cost	A2	=C4-C91
6	Annualized Capital Cost	A3	=C91
7	Fixed Annual O&M Costs	A4	=C85+C92-C6
8	Variable Annual O&M Costs	A5	=C97
9	Capacity (acfy)	A6	=C16*60*C19
10	Variable Annual Costs (\$ / 10 <sup>6</sup> acfy)	A7	=C8*10 <sup>6</sup> /C9
11			
12	<b>Capital Investment</b>		
13	Total Capital Investment (TCI) (DC+TIC)	B1	=C66+C75
14			
15	<b>Model Plant Input Parameters</b>		
16	Flue Gas Flow Rate (acfm)	C1	30225.9
17	Flue Gas Flow Rate (dscfm)	C2	22254.6
18	Flue Gas Moisture (%)	C4	17.25
19	Operational Time (hr/yr)	C5	8000
20			
21	<b>Control Option Design Input Parameters</b>		
22	Increased Pressure Drop (in H <sub>2</sub> O)	D2	2
23	Natural Gas Fuel Cost (\$/1000 ft <sup>3</sup> )	D27	3.5
24	Natural Gas Heating Value (Btu/ft <sup>3</sup> )	D28	990
25	Additional Combustion Air Required (ft <sup>3</sup> air/ft <sup>3</sup> fuel)	D31	11.19
26	Flue Gas Density @STP (lb/ft <sup>3</sup> )	D33	0.074
27	Specific Heat of Flue Gas (Btu/lb °F)	D34	0.253
28	Reheat Increase in Flue Gas Temp (°F)	D36	75
29			
30	<b>Economic Factors</b>		
31	Projected Equipment Life (years)	E1	15
32	Interest Rate (%)	E3	0.07
33	Equipment Capital Recovery Factor (CRFe)	E4	=C32*(1+C32) <sup>C31</sup> /((1+C32) <sup>C31</sup> -1)
34	Retrofit Factor (RF)	E5	1.25
35	Operator Labor (\$/hr)	E6	14
36	Maintenance Labor (\$/hr)	E7	18
37	Electricity Cost (\$/kwh)	E8	0.048
38	Water Cost (\$/1000 gal)	E9	0.2
39	Wastewater Disposal (\$/1000 lb)	E10	0.8
40	Hazardous Waste Disposal Cost (\$/ton)	E11	200
41			
42	<b>Model Plant Calculated Parameters</b>		
43	Required Fuel Flow (scfm)	G26	=C16*1.09*C28/C24/60
44	Required Combustion Air (scfm)	G27	=C43*C25
45			
46	<b>Direct Costs</b>		
47	Purchased Equipment Costs		
48	Reheat Burner Cost	I20	=13149*(C44+C43+0.1*C16) <sup>0.2609</sup>
49	Total Equipment	I23	=C48
50	Instrumentation (0.1*equipment)	I24	=C49*0.1
51	Sales Taxes (0.03*equipment)	I25	=C49*0.03
52	Freight (0.05*equipment)	I26	=C49*0.05

## Reheater -- Cost Model

	A	B	C
53	Purchased Equipment with Tax and Freight	I27	=SUM(C49:C52)
54	Purchased Equipment with Escalation	I28	=C53*1.16885*1.078
55	Purchased Equipment Cost (PEC)	I30	=C54
56	Direct Installation Costs		
57	Foundations and Supports (0.08*PEC)	I31	=0.08*C55
58	Handling and Erection (0.14*PEC)	I32	=0.14*C55
59	Electrical (0.04*PEC)	I33	=0.04*C55
60	Piping (0.02*PEC)	I34	=0.02*C55
61	Insulation for Ductwork (0.01*PEC)	I35	=0.01*C55
62	Painting (0.01*PEC)	I36	=0.01*C55
63	Total Installation Cost	I47	=SUM(C57:C62)
64	Total Installation Cost with Retrofit Factor	I48	=C63*C34
65	Total Direct Installation Cost	I49	=C64
66	Total Direct Cost (DC) (PEC+DIC*RF)	I50	=C65+C55
67			
68	<b>Indirect Installation Costs</b>		
69	Engineering (0.1*PEC)	J1	=0.1*C55
70	Construction and Field Expense (0.06*PEC)	J2	=0.06*C55
71	Contractor Fees (0.1*PEC)	J3	=0.1*C55
72	Start-up (0.01*PEC)	J4	=0.01*C55
73	Performance Test (0.01*PEC)	J5	=0.01*C55
74	Contingencies (0.06*PEC)	J7	=0.06*C55
75	Total Indirect Costs (TIC)	J8	=SUM(C69:C74)
76			
77	<b>Fixed Annual Costs</b>		
78	Direct Annual Costs		
79	Operating Labor		
80	Operator	K1	=1*C19/24*C35
81	Supervisor	K2	=0.15*C80
82	Maintenance		
83	Labor	K3	=0.5*3*C19/24*C36
84	Material	K4	=C83
85	Total Direct Annual Cost (TDAC)	K15	=SUM(C80:C84)
86	Indirect Annual Costs		
87	Overhead (0.6*TDAC)	L1	=0.6*(C80+C81+C83+C84)
88	Administrative Charges (0.02*TCI)	L2	=0.02*C13
89	Property Taxes (0.01*TCI)	L3	=0.01*C13
90	Insurance (0.01*TCI)	L4	=0.01*C13
91	Capital Recovery	L5	=C33*C13
92	Total Indirect Costs (TIAC)	L6	=SUM(C87:C91)
93			
94	<b>Variable Annual Costs</b>		
95	Electricity	M1	=0.000181*C16*C22*C19*C37
96	Fuel Cost	M8	=C43*60*C19*C23/1000
97	Total Variable Annual Costs, TVAC	M10	=SUM(C95:C96)
98			
99	Energy		
100	Electricity	kW/yr	=C95/C37/C19
101	Natural Gas	trillion Btu/yr	=C96/C23/1000
102	Water	1000 gal/yr	
103	Solid Waste	tons/yr	
104	Liquid Waste	gal/yr	

Combustion DOM -- Cost Model

	A	B	C
1	<b>Combustion DOM -- Cost Model</b>		
2			
3	<b>Annual Costs</b>		
4	Total Annual Costs		=SUM(C5:C6)
5	Total Annual O&M Costs		=SUM(C7:C8)
6	Annualized Capital Cost		=C32
7	Fixed Annual O&M Costs		0
8	Variable Annual O&M Costs		0
9	Capacity (acfy)		=C16*60*C18
10	Variable Annual Costs (\$ / 10^6 acfy)		=C8*10^6/C9
11			
12	<b>Capital Investment</b>		
13	\$50,000 + 25% of 17M Capital Cost (includes escalation factor)		=50000+(0.25)*(1.18)*(1.16885*1.082)*(1.715)*(13149)*(C16+C26)^(0.2609)
14			
15	<b>Model Plant Input Parameters</b>		
16	Flue Gas Flow Rate, acfm (input)		6033.5
17	Flue gas flow rate, dscfm (input)		3826.3
18	Operational time (hr/yr)		8000
19			
20	<b>Control Option Design Input Parameters</b>		
21	Natural Gas Heating Value (Btu/ft^3)		990
22	Primary Heat Input (Btu/dscf)		50
23	Afterburner/Primary Heat Input Ratio		0.4
24			
25	<b>Model Plant Calculated Parameters</b>		
26	Required Fuel Flow (scfm)		=C23*C22*C17/C21
27			
28	<b>Economic Factors</b>		
29	Projected Equipment Life (years)		10
30	Interest Rate (%)		0.07
31	Equipment Capital Recovery Factor (CRF)		=C30*(1+C30)^C29/((1+C30)^C29-1)
32	Capital recovery		=C13*C31
33			
34	<b>Energy</b>		
35	Electricity	kW/yr	
36	Natural Gas	trillion Btu/yr	
37	Water	1000 gal/yr	
38	Solid Waste	tons/yr	
39	Liquid Waste	gal/yr	